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**CONSUMER PREFERENCES AND  
THE ABSTRACT MODE MODEL:  
BOSTON METROPOLITAN AREA**

by

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THE ABSTRACT MODE MODEL:  
BOSTON METROPOLITAN AREA

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## INTRODUCTION

Travel demand models predict the number of people who will freely choose to use a given system at a specified level of service. Use is one measure of the "goodness" or effectiveness of a system, and is the end product of many individual consumer trip decisions.

A travel demand model which both predicts system use and provides insights into the factors which influence consumers' preferences and motivations in travel would therefore be a good travel model.

An analysis of consumer preference patterns attempts to get at the very root of trip-making decisions, and may prove vital to a planner conducting a search and evaluation of system policy alternatives. The success of a new system may hinge in large part upon the users' response to the mix of attributes provided by the system. The demand function should therefore facilitate this search and evaluation procedure by measuring the relationship between service attributes and consumer use and determining the marginal changes in service a consumer will accept and still use the system.

One model which offers the planner or designer the capabilities of both predicting system use and measuring the levels of service necessary to attain a given amount of system use is the Abstract Mode Model, formulated by Richard E. Quandt and William J. Baumol of MATHEMATICA for the Department of Commerce (3,4,33,34,35). For the first time since its conception, it was applied to a specific urban area - Metropolitan Boston. Its effectiveness as a prediction device and its applicability as a means of analyzing consumers' motivations and preferences in urban travel was investigated. To enhance this model's use as an analysis tool in a search and choice procedure, the concept of a users' tradeoff ratio was evaluated using an Abstract Mode formulation. Briefly, the tradeoff ratio is the rate of compensating change in value of one travel attribute relative to another (travel time vs. cost for example) that must be realized to maintain a constant level of system use.

CHAPTER ONEMODEL DEFINITION AND DELINEATION OF  
STUDY AREA

## 1.1 WHY THE ABSTRACT MODE MODEL?

A transportation planner seeks to analyze the impact improvements in technology may have on travel demand in the future. The travel mode which will offer these improvements is as yet undetermined. All that is known are the desired characteristics of that mode, such as speed, out-of-pocket cost, comfort, and convenience. Conversely, the designer wishes to determine the importance travellers place on each modal performance characteristic relative to the other modal performance characteristics so that he may compare the relative costs to provide them. He can then improve an existing mode or design a new mode which offers these desired attributes to the public. How should these issues be approached?

To facilitate a planner's search and evaluation of system policy alternatives, the demand function he uses should not be limited to a consideration of specific travel modes. It should encompass all factors considered important to the consumer in his trip-making decisions, and which bear upon his selection of a travel mode, regardless of its name or physical makeup. Any demand models in which travel modes are defined in terms of the administrative entities that control their operations, or in terms of the physical equipment employed, will not provide the planner or designer with answers to his questions. These models have not been formulated with any future modes in mind.

Traditional models, such as the Gravity or Opportunity models, fail in this respect. Travel demand is formulated in terms of specific and conventional modes such as buses, automobiles, and railroad commuter trains. These modes are usually defined in terms of the administrative entities that control their operations, or in terms of the physical equipment employed. They do not take into account the fact that in a world of changing technology, tomorrow's vehicles may differ radically from those of today. In recent years, much research and experimentation has been conducted by different organizations on new modes of travel, such as monorails, ground-effects machines, and fully

automated (driverless automobiles and guideways. Any demand model that defines an automobile as an automobile and a bus as a bus becomes obsolete if a new mode is introduced, because the impact of that new mode cannot be taken into account by any such model that is formulated on the basis of specific modal types.

Previous approaches to travel demand have often neglected the impact that marginal changes in value of various level of service attributes (speed, frequency of service, cost, etc.) have on system use and modal choice. In an evaluation of system policy alternatives, not only are the absolute levels of service a consumer expects from an alternative important, but also the marginal changes in service a consumer will accept and still use the system. Tradeoffs must often be made between values of several modal service and performance attributes, due to cost and locational constraints imposed on a system. To what extent these tradeoffs can be made, within the constraints of factors such as system cost, will influence system use. A demand function is needed which takes into account both absolute values of level of service variables, and the impact that marginal changes in their values will have on demand.

The Abstract Mode Theory has been developed to produce a model that will aid transportation planners and designers in looking ahead into the ever-changing future. This model utilizes a number of abstract modal types, none of which may correspond to any specific present or future mode of transportation. It hypothesizes that a particular mode can be defined by values of several level of service variables such as speed, frequency of service, comfort, and cost (4). This too is a departure from traditional approaches, in that the consumer desires not the commodities themselves (the different travel modes), but rather the different attributes they possess, such as travel time, cost, comfort, and convenience. Thus an existing mode today, such as rail transit, in terms of its service characteristics, can correspond to some abstract mode; a future mode whose physical characteristics have not yet been determined could correspond to some abstract mode merely by specifying the service characteristics desired by its use.

By characterizing a mode in terms of its measurable service and performance attributes, the model also facilitates analysis of the impacts that these attributes will have on system use and modal choice. Of course there is an air of uncertainty involved in a model which only uses measurable attributes of a mode. It will not take into account some immeasurable factors influencing modal choice such as the "prestige" aspects of the automobile, noise, or an aesthetically pleasing trip. Yet these factors are difficult to predict in any kind of model. Hopefully, a mode can be satisfactorily described only in terms of its measurable characteristics.

## 1.2 THE RSTRACT MODE MODEL - DEFINITION

Quandt and Baumol postulate that the travelers choice of mode depends on the mode's attributes, or performance levels relative to the performance levels of the "best" mode (4). Modal split on a given arc in a network is observed as the aggregate of many individual mode choices which depend on the individuals evaluations of the various modes' relative attributes. Total travel along the same arc depends not only on mode split but also on total travel volume. Absolute impedences to travel, such as dollar cost, travel time, and inconvenience are assumed to explain total travel and are measured as the attributes of the best modes. Which is the "best" mode depends on which characteristic is being considered: rapid transit may offer the least travel time between two points in a network and be the "best mode" in that respect; a trip by private automobile may be the least costly between two points in a network, and be the "best mode" in that respect.

Adding to the absolute and relative service attributes of the various modes, environmental factors influencing trip generation and modal choice, such as population, income, and employment, Quandt and Baumol postulate that total intercity trips by a mode is some function of the modal service and performance characteristics, and the demographic and economic characteristics of the population; (3)

$$T_{kij} = f (BEST_{ij}^1, REL_{kij}^1, BEST_{ij}^2, REL_{kij}^2, \dots, BEST_{ij}^n, REL_{kij}^n, Z_{ij}^1, Z_{ij}^2, \dots, Z_{ij}^m) \quad (1.1)$$

Where

$T_{kij}$  = travel volume by mode k between i and j

$BEST_{ij}^x$  = best (cheapest, fastest, etc.) absolute value of travel attribute x of all modes between i and j, where  $x=1, 2, \dots, n$  are different travel attributes being considered.

$REL_{kij}^x$  = actual value of travel attribute x for mode k relative to the best value of attribute x by all modes between i and j

$Z_{ij}^y$  = environmental factors  $y = 1, 2, \dots, m$  such as population and employment levels of nodes i and j, ages and family incomes of the travellers, etc.

The total travel volume by all modes between nodes i and j is equal to the summation of the travel volumes by each mode between nodes i and j, or

$$V_{ij} = \sum_{k=1}^t T_{kij} , \quad (1.2)$$

Where  $V_{ij}$  = total travel volume by all modes

$t$  = number of modes serving nodes i and j

The end result desired from the application of the Abstract Mode Model to the Boston Metropolitan Area is a set of equations which relate the dependent variable, trips by a particular mode, to independent variables influencing trip-making, such as travel time, out-of-pocket cost, and family income. Quandt and Baumol hypothesize that the distribution of the parameters influencing travel demand ( $X_1, X_2, \dots, X_n$ ) is exponential, or the log of the dependent variable (trips) varies linearly with the logs of the independent variables (time, cost, income, etc.). (33)

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} \dots X_n^{\beta_n} , \quad (1.3)$$

or

$$\log Y = \log \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \dots + \beta_n \log X_n ,$$

where Y = trips by a particular mode

$\beta_0$  = constant

$\beta_1$  to  $\beta_n$  = coefficients of independent variables (estimated)

$X_1$  to  $X_n$  = independent variables influencing trip-making

$n$  = total number of independent variables

On the other hand, Blackburn postulates that the distribution of the parameters influencing travel demand is linear, or the dependent variable (trips) varies linearly with the independent variables (time, cost, income, etc.) (33). Using the same variables and subscripts as before, the equation takes the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$$

Both these hypotheses, simple linearity and logarithmic linearity, were tested to see which was more successful in explaining a substantial fraction of the variation in the dependent variable. The same analytical technique, multiple regression, was applied to both.

Quandt and Baumol formulated their model with intercity travel in mind. The applications of the model, prior to this study, have been restricted to this type of travel. To the author's knowledge, this study is the first attempt by anyone to test the effectiveness of the model as a prediction device in urban (intracity) travel.

### 1.3 STUDY AREA - METROPOLITAN BOSTON

The entire study area encompassed 152 cities and towns within the Boston Metropolitan Region, which were subdivided into 626 traffic subzones and fractions thereof. Only trips between the first 148 subzones were considered because they were all accessible by the six modes of travel considered important in an urban study of this sort:

1. Auto driver
2. Auto passenger
3. Subway or streetcar passenger
4. Trackless trolley or bus passenger
5. Taxi passenger
6. Railroad commuter train passenger

The towns included within these 148 subzones were those focused around central Boston itself, and contain the bulk of the population and daily travel in this area:

1. Boston Proper
2. East Boston
3. South Boston
4. Charlestown
5. North Dorchester
6. South Dorchester
7. Roxbury
8. West Roxbury
9. Mattapan
10. Hyde Park
11. Roslindale
12. Fenway - Jamaica Plain
13. Brighton
14. Brookline
15. Newton

This area is enclosed in Figure 1.1. Figure 1.2 presents a more detailed breakdown by subzones of the towns contained within the city of Boston (125 of 148 total subzones). Brookline and Newton are not considered as parts of the city of Boston itself (remaining 23 subzones).

The data to be used as input to the multiple regression routines is taken from one of the 1963 home-interview surveys undertaken by Wilbur Smith and Associates for the Boston Regional Planning Project, a 3% sampling of the dwelling units contained in the study area, and is the Person-Trip Report ("02") Survey. To recognize the fact that travel patterns and consumer preferences may differ during the peak and offpeak hours of the day, the data sets were subdivided into these two general

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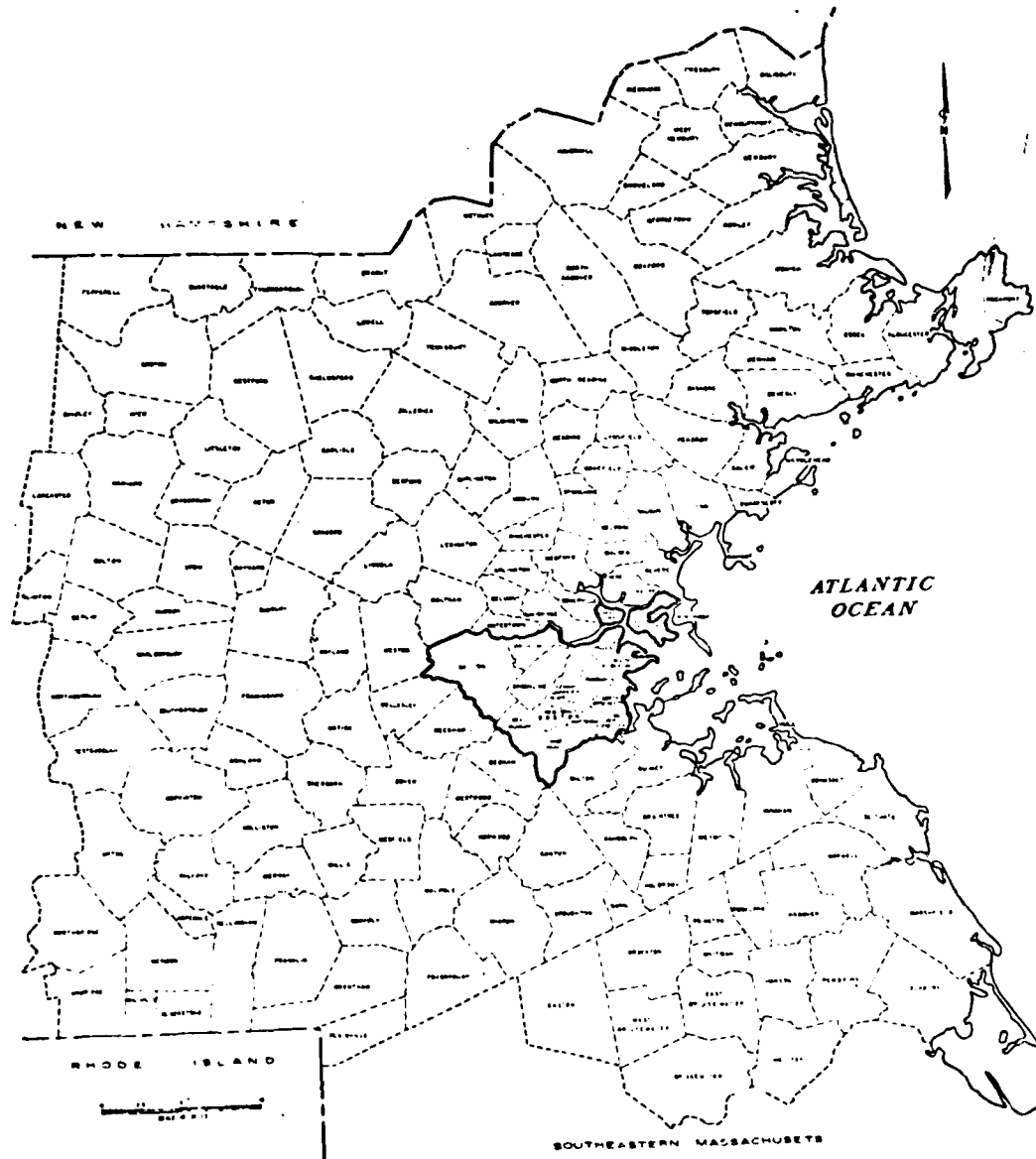


Figure 1.1

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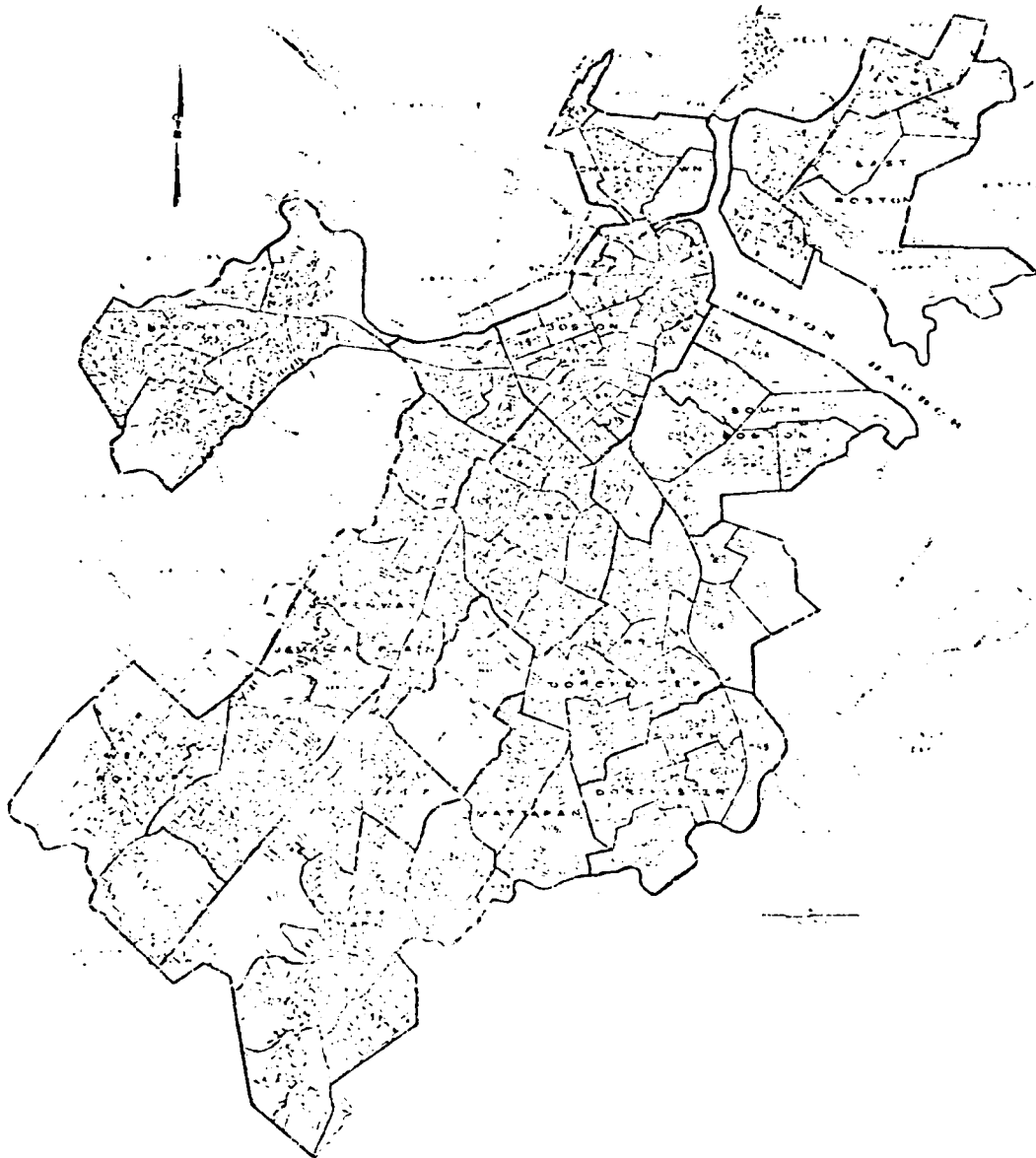


Figure 1.2

Traffic Zones, City of Boston

time divisions. Those trips occurring between 7 A.M. to 9 A.M. and 4 P.M. to 6 P.M. constituted peak-hour trips; those trips occurring between 6 A.M. to 7 A.M., 9 A.M. to 4 P.M., and 6 P.M. to 12 P.M. constituted offpeak-hour trips.

Certain characteristics of the survey data should be noted at this point, since they later had a bearing in the formulation of the estimating equations and on the character of results obtained from regression.

Rather than a trip being defined as beginning from the initial origin of the traveler and ending at his final destination, where more than one travel mode (transfers) could be involved, the "02" Survey defined its trip as one undertaken by a single mode. A trip where a traveler would drive his car to a railroad station and then take a commuter train to his final destination would constitute two trips by the "02" Survey's definition; a trip where a traveler took a rapid rail train to an intermediate destination and then transferred to another rapid rail train to arrive at his final destination would constitute two trips by the "02" Survey's definition.

The author contends that modal trips, rather than complete trips, have been recorded by this study, which eliminates the transfer problem, but also underestimates the total time spent in travel. This trip definition also tends to distort the use of indicators of the attractiveness of trip-ends, such as population and employment levels, because it defines trans-shipment points (intermediate destinations where transfers are made) as the ultimate destination of the traveler.

Secondly, a majority of the person-trip observations for the auto-driver and auto-passenger modes possessed zero values for walk time and out-of-pocket cost, as did the walk time values for person-trips by the taxi mode. It is an indication that travelers only perceive the immediate cost at that point in time when the trip is taking place as their out-of-pocket cost. For automobile trips, no money comes out of their pockets. They also consider walking to and from their autos at the trip origin and destination as inconsequential compared to other factors such as travel time. In effect they are saying that they step from their front door into their autos at the trip origin, and step from their autos into the store, place of business, etc. at the trip destination.

#### 1.4 INPUT PARAMETERS TO THE MODEL

Twenty-three variables were extracted from the person-trip observations as possible input parameters for the Abstract Mode functional forms to be estimated by multiple regression techniques. These parameters can be aggregated into three general groupings:

- I. Dependent Variables - travel volume
- II. Independent Variables - modal service and performance attributes
- III. Independent Variables - environmental descriptors of the traveler, or of the origin and destination nodes.

Before each input parameter and its meaning in an Abstract Mode formulation is enumerated, its use in a given functional form, and the character of the resulting estimating equation should be emphasized.

Quandt and Baumol formulated their Abstract Mode Theory so that a resulting estimating equation could be used to predict modal split and/or trip generation by any mode, whether known or unknown, existing or abstract. To accomplish this, each mode was characterized by the type of service it offered to the public in terms of a set of travel parameters, such as travel time, walk time, and cost. The performance level of each mode relative to the other modes for each travel attribute was measured in three ways:

1. The actual value of each travel attribute possessed by each mode between each O-D pair
2. The best value of each travel attribute by any mode between each O-D pair
3. The ratio of the actual value of a travel attribute by a mode to the best value of that same travel attribute by any mode between a given O-D pair.

With all modes being characterized on a common basis with respect to a set of travel attributes, the set of observations used as input to regression consisted of trip-observations by all modes between all O-D pairs. There was no stratification of observations by mode or by O-D pair. The estimating equations that resulted predict the travel volume a given mode possesses between any O-D pair based on the observed travel characteristics of all the alternative modes within the sampling area.

A given estimating equation is perfectly general with respect to travel modes and O-D pairs, and in this sense is an "abstract mode" equation. The reader is asked to keep this in mind as the discussion proceeds, so that input parameters calculated on the origin-destination-mode

basis or origin-destination-all-modes basis will not be confused with the character of the equation estimated and the type of output its use will provide.

A summary of all the possible input parameters to the estimation of an Abstract Mode Formulation is listed in Table 1.1.

Table 1.1

## Input Parameters

		<u>VARIABLE</u>	<u>INTERPRETATION</u>
Y M O D A L F O R M A N C E		$(PTRIPS)_{kij}$	Percent of total trips by mode k between nodes i and j
		$(ATRIPS)_{kij}$	Actual number of trips by mode k between nodes i and j
		$(AVET)_{kij}$	Mean travel time by mode k between nodes i and j
		$(RELT)_{kij}$	Relative mean travel time by mode k between nodes i and j ( $AVET/BESTTM$ )
		$(BESTTM)_{ij}$	Mean travel time of fastest mode between nodes i and j
		$(AVEWT)_{kij}$	Mean walk time for mode k between nodes i and j
		$(RELWT)_{kij}$	Relative mean walk time for mode k between nodes i and j ( $AVEWT/BESTWT$ )
		$(BESTWT)_{ij}$	Mean walk time of mode with least walk time between nodes i and j
		$(AVECT)_{kij}$	Mean cost by mode k between nodes i and j
		$(RELCT)_{kij}$	Relative mean cost by mode k between nodes i and j ( $AVECT/BESTCT$ )
E N V I R O N M E N T A L		$(BESTCT)_{ij}$	Mean cost of lowest-cost mode between nodes i and j
		$(ANODRI)_{kij}$	Percent of travellers using mode k between nodes i and j under 16 or over 59 years old
		$(ALNODR)_{ij}$	Percent of travellers using any mode between nodes i and j under 16 or over 59 years old
		$(AUTO)_{kij}$	Mean number of autos per household of travellers using mode k between nodes i and j
		$(ALAUTO)_{ij}$	Mean number of autos per household of travellers using any mode between nodes i and j
		$(AINCOM)_{kij}$	Mean coded family income of travellers using mode k between nodes i and j
		$(ALINCH)_{ij}$	Mean coded family income of travellers using any mode between nodes i and j
		$(DLIC)_{kij}$	Percent of travellers with driver's licenses using mode k between nodes i and j
		$(ALDLIC)_{ij}$	Percent of travellers with driver's licenses using any mode between nodes i and j
		$(POP)_i$	Resident population of origin zone i
		$(POP)_j$	Resident population of destination zone j
		$(EMPLOY)_i$	Employed residents in origin zone i
		$(EMPLOY)_j$	Employed residents in destination zone j

CHAPTER TWO

## THE TRADEOFF RATIO CONCEPT

## 2.1 THE TRADEOFF RATIO - BACKGROUND AND DEFINITION

The unique framework of Quandt and Baumol's formulations, where all travel modes are characterized by the same service and performance attributes, offers the planner or designer a means with which to evaluate consumer preferences in travel.

It was stated earlier that demand models predict the "goodness" of a given physical system, and in transportation, a measure of the "goodness" or effectiveness of a system is the number of people who use it. One system is at least as "good" as another if the same number of people will use that system as will use another system.

Very seldom will a single mode possess all the "best" values for all travel attributes between a given O-D pair, and thus be the most attractive to the consumer in all respects. Moreover, few travelers will value travel time, walk time, and cost equally when making trip decisions. This is one of the "gray areas" of transportation analysis, that of evaluating a given system as seen from the eyes of the consumer. If one envisions an urban transportation system as a competitive market place, the alternative travel modes are then substitutable products that are up for sale to the consumer. The consumer will choose (buy) the particular transportation facility (product) which gives him the closest approximation to the given set of values for travel attributes he desires (i.e., "X" minutes travel time, "Y" minutes walk time, "Z" cents cost). A planner or designer who wishes to put a new product (new or improved travel mode) on the market, will only do so if the product will be purchased (used) in some sufficient quantity. In order for a new product to achieve maximum use, it must provide the type of service to which individuals will respond - the service attributes which correspond to the traveler's preferences. Once the tradeoffs which must be made between values of several different modal service attributes are known, the designer can design a "new" mode for maximum consumer satisfaction.

Given a general equation in linear form, such that

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n, \quad (2.1)$$

where  $Y$  = number of trips (travel volume),

$X_1$  to  $X_n$  = different travel attributes of a mode,

$\beta_0$  to  $\beta_n$  = coefficients of  $X_i$  estimated by least-squares method of regression.

A transportation analyst wishes to determine how much a small change in value of one service attribute will affect a correspondingly small change in value of another service attribute, so that a constant travel volume will be maintained. From equation (2.1),

$$\frac{dY}{dX_1} = \beta_1, \frac{dY}{dX_2} = \beta_2, \dots, \frac{dY}{dX_n} = \beta_n,$$

and the effect of a small change in  $X_1$  on a small change in  $X_2$  is

$$\frac{\frac{dY}{dX_1}}{\frac{dY}{dX_2}} = \frac{\beta_1}{\beta_2}$$

or is the change in value of  $X_1$  per unit change in value of  $X_2$  so that  $dY = \text{constant}$

The ratio  $\frac{dY/dX_1}{dY/dX_2}$  is designated as the Tradeoff Ratio  $T_{12}$ , and can be generalized for all travel attributes ( $X_1$  to  $X_n$ ) by the form

$$T_{ab} = \frac{dY/dX_a}{dY/dX_b}, \quad a \neq b, \quad (2.2)$$

$$T_{ab} = 1, \quad a = b,$$

where  $a$  = travel attribute  $X_m$  ( $m = 1, 2, \dots, n$ ), such that  $\beta_a$  is the coefficient of travel attribute  $X_a = X_m$

$b$  = travel attribute  $X_{(m+\lambda)}$  ( $\lambda = \pm 1, \pm 2, \dots, \pm (n-1)$ ), such that  $\beta_b$  is the coefficient of travel attribute  $X_b = X_{(m+\lambda)}$  ( $X_m + \lambda \neq X_m$ ).

The Tradeoff Ratio as defined here is a rate of compensating change in value of one travel attribute relative to another. It is the relative importance or utility of a travel attribute in the eyes of the marginal consumer when making a trip decision.

## 2.2 DERIVATION OF THE TRADEOFF RATIOS FROM AN ABSTRACT MODE FORMULATION

Qualitatively, the Tradeoff Ratio is a value which expresses how a small change in value of one travel attribute will affect a correspondingly small change in value of another travel attribute at some constant travel volume. As applied to an Abstract Mode formulation, two different cases must be examined:

Case 1 - Abstract Mode equations in linear form

Case 2 - Abstract Mode equations in exponential form  
(linear in logs of the variables)

### Case 1 - Linear Abstract Mode Equations

A general formulation of a linear Abstract Mode equation can be defined as:

$$Y = \beta_0 + \beta_{RT} X_{RT} + \beta_{BT} X_{BT} + \beta_{RW} X_{RW} + \beta_{BW} X_{BW} + \beta_{RC} X_{RC} \\ + \beta_{BC} X_{BC} + \sum_{m=1}^n \beta_m X_m$$

where  $X_{RT}$  = Relative travel time by mode k between i and j

$X_{BT}$  = Best travel time by any mode between i and j

$X_{RW}$  = Relative walk time by mode k between i and j

$X_{BW}$  = Best walk time by any mode between i and j

$X_{RC}$  = Relative cost by mode k between i and j

$X_{BC}$  = Best cost by any mode between i and j

$X_m$  ( $m = 1, \dots, h$ ) = Environmental descriptors of the traveler, or  
or nodes i and j

Ideally, the transportation planner or designer would like to express the relationships that exist between various modal service and performance attributes in terms of their actual values, rather than in terms of their "best" or "relative" values, as defined by an Abstract Mode formulation.

In an equation such as (2.3), where actual values of each independent travel attribute are not included, the following transformation can be made:

$$\text{RELATIVE} = \text{ACTUAL} / \text{BEST},$$

or

(2.4)

$$X_{RT} = X_{AT}/X_{BT}, X_{RW} = X_{AW}/X_{BW}, X_{RC} = X_{AC}/X_{BC},$$

where  $X_{AT}$  = Actual travel time by mode k between i and j

$X_{AW}$  = Actual walk time by mode k between i and j

$X_{AC}$  = Actual cost by mode k between i and j

The "best" characteristic of a given travel attribute is independent of the "actual" characteristic of that same attribute only when the mode(s) possessing this value is not the "best" (fastest, cheapest, etc.) mode(s) in that respect. When a mode possesses an actual value for a travel attribute that is equal to the "best" value by all modes, the "actual" and "best" values are dependent on each other.

In the case of dependence ( $X_{AT} = X_{BT}$ ,  $X_{AW} = X_{BW}$ , or  $X_{AC} = X_{BC}$ ), the "relative" value is a constant (equal to one) for the mode whose "actual" value for a given travel attribute is equal to the "best" value by any mode for that same attribute. In the case of independence ( $X_{AT} \neq X_{BT}$ ,  $X_{AW} \neq X_{BW}$ , or  $X_{AC} \neq X_{BC}$ ), when the "actual" characteristic of a given travel attribute is being considered for a mode(s), the "best" characteristic of that same travel attribute is a constant for that mode(s), since the two values are properties of different modes. The "actual" value of the travel characteristic can change for this situation without affecting the value of the "best" characteristic until the point is reached where these values are equal. When these values are equal, the "actual" characteristic is no longer independent of the "best" characteristic, and the dependence situation exists.

The small change in value of one travel attribute relative to a small change in value of another will yield a different result depending upon which situation, dependence or independence, exists between the "relative" and "best" values for each travel attribute contained in an Abstract Mode Formulation.

Situation 1 - Dependence

Dependence holds when the actual value of a travel attribute by mode "k" between nodes "i" and "j" corresponds to the best (cheapest, fastest, etc.) value by any mode between "i" and "j" ( $X_{AT} = X_{BT}$ ,  $X_{AW} = X_{BW}$ , or  $X_{AC} = X_{BC}$ ). For example, if  $X_{AT} = X_{BT}$ , substitution of equation (2.4) into equation (2.3) yields:

$$Y = \beta_0 + \beta_{RT}(X_{AT}/X_{BT}) + \beta_{BT}X_{BT} + \beta_{RW}X_{RW} + \dots, \quad (2.5)$$

and since  $X_{AT} = X_{BT}$ ,

$$Y = \beta_0 + \beta_{RT} + \beta_{BT}X_{AT} + \beta_{RW}X_{RW} + \dots, \quad (2.6)$$

and

$$\frac{dY}{dX_{AT}} = \beta_{BT}, \text{ for } X_{AT} = X_{BT} \quad (2.7)$$

Situation 2 - Independence

Independence holds when the actual value of a travel attribute by mode "k" does not correspond to the best value (cheapest, fastest, etc.) by any mode between "i" and "j" ( $X_{AT} \neq X_{BT}$ ,  $X_{AW} \neq X_{BW}$ , or  $X_{AC} \neq X_{BC}$ ). For example, if  $X_{AT} \neq X_{BT}$ , equation (2.5) still holds:

$$Y = \beta_0 + \beta_{RT}(X_{AT}/X_{BT}) + \beta_{BT}X_{BT} + \beta_{RW}X_{RW} + \dots, \quad (2.5)$$

and  $X_{BT}$  can be considered as a constant when differentiating with respect to  $X_{AT}$ , just as  $X_{RW}$ ,  $X_{BW}$ , etc. are considered as constants. Therefore,

$$\frac{dY}{dX_{AT}} = \beta_{RT}/X_{BT}, \text{ for } X_{AT} \neq X_{BT} \quad (2.8)$$

The same types of relationships for situations (1) and (2) will hold for the walk time and cost attributes.

Since the tradeoff ratios with respect to out-of-pocket cost for example, have been defined as:

$$T_{TC} = \frac{\frac{dY}{dX_{AT}}}{\frac{dY}{dX_{AC}}}, \quad T_{WC} = \frac{\frac{dY}{dX_{AW}}}{\frac{dY}{dX_{AC}}}, \quad TCC = \frac{\frac{dY}{dX_{AC}}}{\frac{dY}{dX_{AC}}} = 1 \quad (2.9)$$

$$\text{If } X_{AT} = X_{BT}, \quad \frac{dY}{dX_{AT}} = \beta_{BT} \quad (2.10)$$

$$\text{If } X_{AT} \neq X_{BT}, \quad \frac{dY}{dX_{AT}} = \beta_{RT}/X_{BT} \quad (2.11)$$

$$\text{If } X_{AW} = X_{BW}, \quad \frac{dY}{dX_{AW}} = \beta_{BT} \quad (2.12)$$

$$\text{If } X_{AW} \neq X_{BW}, \quad \frac{dY}{dX_{AW}} = \beta_{RW}/X_{BW} \quad (2.13)$$

$$\text{If } X_{AC} = X_{BC}, \quad \frac{dY}{dX_{AC}} = \beta_{BC} \quad (2.14)$$

$$\text{If } X_{AC} \neq X_{BC}, \quad \frac{dY}{dX_{AC}} = \beta_{RC}/X_{BC} \quad (2.15)$$

Either (2.10) or (2.11), either (2.12) or (2.13), and either (2.14) or (2.15) will exist depending upon which mode "k" of the "m" possible modes is being evaluated, and depending upon the relationship between values of its travel attributes and values of the same travel attributes of the other "m-1" modes.

The objective function is then:

$$\text{C.E. Units} = T_{TC}X_{AT} + T_{WC}X_{AW} + T_{CC}X_{AC} \quad (2.16)$$

and

$$\text{Trips} = f(\text{C.E. Units}, k)$$

where C.E. Units = Travel attributes' contribution to travel volume, in terms of cost-equivalent units

K = constant = contributions of remaining environmental factors to travel volume in an Abstract mode formulation

### Case 2 - Exponential (linear-in-log) Abstract Mode Equations

A general formulation of an exponential Abstract Mode equation can be defined as:

$$Y = \beta_0 X_{RT}^{\beta_{RT}} X_{BT}^{\beta_{BT}} X_{RW}^{\beta_{RW}} X_{BW}^{\beta_{BW}} X_{RC}^{\beta_{RC}} X_{BC}^{\beta_{BC}} X_i^{\beta_i} \dots X_m^{\beta_m}, \quad (2.17)$$

where the variables and subscripts have the same meaning as in the linear case. In logarithmic form, equation (2.17) could be expressed as:

$$\begin{aligned} \log Y = & \log \beta_0 + \beta_{RT} \log X_{RT} + \beta_{BT} \log X_{BT} + \beta_{RW} \log X_{RW} + \beta_{BW} \log X_{BW} \\ & + \beta_{RC} \log X_{RC} + \beta_{BC} \log X_{BC} + \beta_i \log X_i + \dots + \beta_m \log X_m \end{aligned} \quad (2.18)$$

Again it is desirable to work in terms of the actual values of a travel attribute, rather than in terms of a travel attribute's "relative" or "best values, so the transformations

RELATIVE = AVERAGE/BEST

or

$$X_{RT} = X_{AT}/X_{BT}, \quad X_{RW} = X_{AW}/X_{BW}, \quad X_{RC} = X_{AC}/X_{BC} \quad (2.4)$$

are used. As in the linear case, two situations arise:

1. Dependence - the actual value of a travel characteristic for the mode being considered is also the "best" value of that same characteristic for any mode.
2. Independence - the actual value of a travel characteristic for the mode being considered is not equal to the "best" value of that same characteristic for any mode.

Situation 1 - Dependence

$$(X_{AT} = X_{BT}, X_{AW} = X_{BW}, \text{ or } X_{AC} = X_{BC})$$

For example if  $X_{AT} = X_{BT}$ , substitution of (2.4) into equation (2.18) yields:

$$\log Y = \log \beta_0 + \beta_{RT} \log(X_{AT}/X_{BT}) + \beta_{BT} \log X_{BT} + \beta_{RW} \log X_{RW} + \dots, \quad (2.19)$$

and since  $X_{AT} = X_{BT}$ ,

$$\log Y = \log \beta_0 + \beta_{RT} \log(1) + \beta_{BT} \log X_{AT} + \beta_{RW} \log X_{RW} + \dots \quad (2.20)$$

Differentiating with respect to  $X_{AT}$ ,

$$\frac{d(\log Y)}{dX_{AT}} = \frac{\beta_{BT} d(\log X_{AT})}{dX_{AT}} = \beta_{BT}/X_{AT}, \text{ for } X_{AT} = X_{BT} \quad (2.21)$$

Situation 2 - Independence

$$(X_{AT} \neq X_{BT}, X_{AW} \neq X_{BW}, \text{ or } X_{AC} \neq X_{BC})$$

For this situation, if  $X_{AT} \neq X_{BT}$ , after the transformation ( $X_{RT} = X_{AT}/X_{BT}$ ) is made, equation (2.19) still holds, or:

$$\log Y = \log \beta_0 + \beta_{RT} \log(X_{AT}/X_{BT}) + \beta_{BT} \log X_{BT} + \beta_{RW} \log X_{RW} + \dots \quad (2.19)$$

Differentiating with respect to  $X_{AT}$ ,

$$\frac{d(\log Y)}{dX_{AT}} = \frac{\beta_{RT} d \log(X_{AT}/X_{BT})}{dX_{AT}} = \beta_{RT}/(X_{AT} X_{BT}), \text{ for } X_{AT} \neq X_{BT} \quad (2.22)$$

Again, the same types of relationships for situations (1) and (2) will hold true for the walk time and cost travel attributes, giving rise to the following tradeoff ratios with respect to out-of-pocket cost:

$$T_{TC} = \frac{\frac{d(\log Y)}{dX_{AT}}}{\frac{d(\log Y)}{dX_{AC}}}, \quad T_{WC} = \frac{\frac{d(\log Y)}{dX_{AW}}}{\frac{d(\log Y)}{dX_{AC}}}, \quad T_{CC} = \frac{\frac{d(\log Y)}{dX_{AC}}}{\frac{d(\log Y)}{dX_{AC}}} = 1 \quad (2.23)$$

$$\text{If } X_{AT} = X_{BT}, \quad \frac{d(\log Y)}{dX_{AT}} = \beta_{BT}/X_{AT} \quad (2.24)$$

$$\text{If } X_{AT} \neq X_{BT}, \quad \frac{d(\log Y)}{dX_{AT}} = \beta_{RT}/(X_{AT}X_{BT}) \quad (2.25)$$

$$\text{If } X_{AW} = X_{BW}, \quad \frac{d(\log Y)}{dX_{AW}} = \beta_{BW}/X_{AW} \quad (2.26)$$

$$\text{If } X_{AW} \neq X_{BW}, \quad \frac{d(\log Y)}{dX_{AW}} = \beta_{RW}/(X_{AW}X_{BW}) \quad (2.27)$$

$$\text{If } X_{AC} = X_{BC}, \quad \frac{d(\log Y)}{dX_{AC}} = \beta_{BC}/X_{AC} \quad (2.28)$$

$$\text{If } X_{AC} \neq X_{BC}, \quad \frac{d(\log Y)}{dX_{AC}} = \beta_{RC}/(X_{AC}X_{BC}) \quad (2.29)$$

Either (2.24) or (2.25), either (2.26) or (2.27), and either (2.28) or (2.29) will exist depending upon which mode "k" of the "m" possible modes is being evaluated, and depending upon the relationship between values of travel attributes and values of the same travel attributes for the other "m-1" modes.

The objective function is then:

$$\log(\text{C.E. Units}) = T_{TC} \log X_{AT} + T_{WC} \log X_{AW} + T_{CC} \log X_{AC} \quad \text{and} \quad (2.30)$$

$$\log(\text{Trips}) = f(\log(\text{C.E. Units}), \log(K))$$

### 2.3 THE TRADEOFF RATIO - IMPLICATIONS FOR TRANSPORT PLANNING AND DESIGN

If the effectiveness of a transport system can be measured by volume of travel, then :

Travel volume =  $f(\text{travel time, walk time, out-of-pocket cost, comfort, etc.})$

is a measure of effectiveness which can be used in design. (2.31)

The transportation planner would like to provide a new system which maximizes travel volume (consumer satisfaction) per dollar spent in constructing, operating, and maintaining the facility. There are many different combinations of the travel attributes possible, but the optimum combination of travel attributes is that which maximizes the amount of satisfaction (Travel Volume) obtainable from a given facility. The tradeoff ratio is a measure of the relative importance of the system attributes and therefore is a guide to selecting the satisfaction maximizing mix of attributes. It, in effect, tells the system designer which performance characteristics should be changed.

A utility function such as equation 2.31 was not treated in any further depth in this study, beyond its description here of its possible significance in transport planning and design. The author's intent was to suggest the role the tradeoff ratio concept could play in a system or network evaluation of alternative transportation facilities. Specific tradeoff ratios were calculated, however, from the estimated Abstract Mode formulations for the Boston Region. (Chapter 3).

CHAPTER THREE

## MODEL EVALUATION

## 3.1 THE ABSTRACT MODE MODEL - SUMMARY

Before expanding in detail the empirical results found in applying the Abstract Mode Model to the Boston Metropolitan Area, general comments can be made on the effectiveness of this model as a prediction device, and as a tool, along with the tradeoff ratio concept, to analyze consumer preferences and motivations in travel (and aid the planner in his search and evaluation of system policy alternatives).

If the null hypothesis of this research study was that the Abstract Mode Model can be used to predict demand for urban transportation, conclusive evidence was not found to reject this hypothesis. The fitted equations tended to indicate that either the particular travel parameters chosen do not by themselves completely explain variations in consumer travel behavior, or that consumer preferences in urban travel are random, and cannot be fully described by the measurable attributes of a travel mode. Poor statistical fits that did occur appeared to result more from sample biases and aggregation problems inherent in the data base used, than from the analytical concepts of the Abstract Mode Model.

Better statistical fits and significance were obtained from logarithmic regressions than from linear regressions, adding support to Quandt and Baumol's linear-in-logs hypothesis. In most cases, better fit and significance were obtained for those formulations having percent travel volume by a mode as the dependent variable, rather than actual travel volume by a mode, indicating that this model is better suited to pure modal split rather than to both trip generation and modal split.

The model's use, along with the tradeoff ratio concepts, as a tool to analyze consumer preference patterns, produced interesting results. Consumer travel patterns were found to vary according to the time of day in which the trip takes place. In most regressions, good correlation was found to exist between the cost variables and travel volume, while little or no correlation was found to exist between the travel time variables and travel volume, contradicting the generally accepted fact that travel time is the single travel attribute which contributes the most explanatory power to a travel demand estimation procedure, while out-of-pocket cost exerts only a secondary influence.

Calculating the tradeoff ratio of travel time with respect to out-of-pocket cost from the regressions resulted in an average value of one minute of peak hour travel time being equivalent to 5.8 cents out-of-pocket cost. With this value, the dollar value a traveler places on his time spent in peak hour travel was calculated, 3.48/hour. Placing more importance on the general magnitude of this value rather than on its specific value, leads to the conclusion that past estimates of the value of a traveler's time, such as the minimum wage, may grossly understate its true value. Furthermore, one hard and fast value cannot be placed on a traveler's time.

The remainder of this chapter will be spend expanding and clarifying the issues brought up in this section. The reader is asked to keep these conclusions in mind as the discussion proceeds.

### 3.2 STATISTICAL EVALUATION - CONCLUSIONS

A comprehensive series of regressions was performed, encompassing many possible combinations of the 23 modal travel attributes and environmental characteristics described earlier, in both linear and logarithmic form, and for peak hour and offpeak hour travel. The input data was stratified on a subzone basis and on a town basis for origin-destination zone considerations. It was further stratified by 6 specific travel modes (auto, auto driver, trackless trolley or bus, subway or streetcar, rail commuter, and taxi), and also by the three more general modes, auto, transit, and taxi. Tables 3.1 to 3.4 contain a condensed listing of the key statistical quantities estimated for the regressions, using survey data aggregated at the origin-subzone, destination-subzone basis (148 subzones) and by the six specific travel modes, while Tables 3.5 and 3.6 contain the same quantities estimated at the origin-town, destination-town basis, and by the three general travel modes. The upper value in each block is the variable's estimated regression coefficient ( $\beta$ ), and the lower value is the variable's computed "t" statistic for that functional form. Below are listed the "R" and "F" values for each functional form.

Because the total number of quantities estimated is very large, a detailed evaluation of each of these quantities is beyond the scope of this report, and would not reflect what the author sought to accomplish in this study. The level of detail to be employed in this evaluation, will be in keeping with the questions the author sought these estimates to answer,

Excluded for 2

Total Number of Freedom - 180

Table J.2  
Peak-hour Logarithmic Regressions

Functional Form												
VARIABLE	1	2	3	4	5	6	7	8	9	10	11	12
Y	PTRIIPS	PTRIIPS	PTRIIPS	PTRIIPS	ATRIIPS	ATRIIPS	ATRIIPS	ATRIIPS	ATRIIPS	ATRIIPS	ATRIIPS	ATRIIPS
CONSTANT	-.10460	-.09440	-.10754	-.09873	.07123	.07120	.11548	.08450	.08441	.10828	.07962	.10134
(ATRIIP) <sub>K1J</sub>						-.01661			.00955			
						-.245			.143			
(RESLT) <sub>K1J</sub>	-.02523	-.03037	-.02954	-.02558	.22850	.24517	.24378	.26614	.25657	.24335	.25029	.24987
	-.243	.252	-.275	-.240	1.743	2.055	1.852	2.037	2.190	1.842	1.893	1.889
(DESTOT) <sub>K1J</sub>					-.01670		-.00159	.00544		.00377	.00835	.00826
					-.247		-.024	.140		.056	.130	.121
(ALVWD) <sub>K1J</sub>						.05355			.05646			
						1.816			1.940			
(EDVWD) <sub>K1J</sub>	-.02930	-.02520	-.02652	-.02013	.07026	.01672	.07357	.07555	.01912	.08068	.07497	.07517
	-.619	-.524	-.501	-.601	1.327	.295	1.511	1.440	.341	1.533	1.420	1.424
(BUSTW) <sub>K1J</sub>					.05351		.04958	.05642		.05759	.05313	.05445
					1.814		1.677	1.939		1.938	1.794	1.854
(AVDCT) <sub>K1J</sub>						-.00912			-.01050			
						-.388			-.456			
(RELCT) <sub>K1J</sub>	-.13283	-.13225	-.13338	-.13045	.00951	.01873	.02156	.01667	.02717	.01683	.01781	.01714
	-.3.360	-.3.653	-.3.250	-.3.874	.253	.471	.571	.447	.623	.445	.471	.454
(DESTOT) <sub>K1J</sub>					-.00961		-.00671	-.01047		-.01150	-.01017	-.00979
					-.357		-.287	-.455		-.490	-.436	-.419
(ALVWD) <sub>K1J</sub>			-.00897									
			-.151									
(ALVWD) <sub>K1J</sub>												.02171
												.388
(AUTO) <sub>K1J</sub>				.07676			.06605					
				.868			1.421					
(ALVWD) <sub>K1J</sub>										-.04745		
										.158		
(ALVWD) <sub>K1J</sub>		-.01104	-.01177				.06942	.06941				
		-.342	-.360				1.972	1.972				
(ALVWD) <sub>K1J</sub>											.04035	.04194
											1.029	1.062
(DLIC) <sub>K1J</sub>		.02033					.05413	.05413				
		.489					1.203	1.203				
(ALVWD) <sub>K1J</sub>											.01918	
											-.358	
(FCP) <sub>K1J</sub>					.02256	.02255	.66667	.57521	-.57802	.66667	-.66667	-.66667
					1.275	1.975	-2.338	-2.022	-2.022	-2.331	-2.242	-2.234
(FCP) <sub>K1J</sub>					.00063	.00057	-.00918	-.00424	-.00485	-.00214	-.00668	-.00921
					.079	.079	-1.011	-.885	-.865	-.943	-.902	-.981
(NATION) <sub>K1J</sub>						.75648	.65631	.65640	.75661	.72659	.72656	
						2.427	2.095	2.097	2.410	2.314	2.303	
(LIFTIOY) <sub>K1J</sub>						.03419	.03065	.03065	.03069	.03257	.03536	
						1.163	1.049	1.049	1.140	1.112	1.170	
q	.40195	.42350	.42276	.42673	.35163	.35167	.40323	.42925	.42929	.39701	.40419	.40433
r	12.729	7.667	7.617	9.760	3.033	3.034	3.039	3.167	3.163	2.874	2.734	2.734

Total 2000 of 10000 - 150

NOT REPRODUCIBLE

Table 3.3

Off-peak-hour Linear Regressions

VARIABLE	Functional Form											
	1	2	3	4	5	6	7	8	9	10	11	12
T	FTrips	FTrips	FTrips	FTrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips
CONSTANT	.82259	.80271	.81821	.84632	1.5748	1.2029	1.7056	1.9479	1.7236	1.7344	2.1729	1.6100
(AVT) $K_{1j}$						-.01185 -4.436			-.01190 -4.465			
(REL) $K_{1j}$	-.05571 -9.726	-.05501 -9.562	-.05567 -9.719	-.05569 -9.859	.02686 .575	.16033 3.238	.01748 .378	.04969 .210	.14618 2.929	.02224 .483	.02214 .483	.02747 .600
(BESTM) $K_{1j}$					-.01780 -4.611		-.01780 -4.612	-.01779 -4.616		-.01767 -4.560	-.01760 -4.561	-.01746 -4.713
(AVT) $K_{1j}$						-.00613 -1.544			-.01346 -1.180			
(REL) $K_{1j}$	-.00219 -8.654	-.00216 -8.439	-.00218 -8.602	-.00223 -8.770	.00344 1.717	.00398 1.806	.00364 1.411	.00243 1.257	.00377 1.714	.00315 1.584	.00272 1.364	.00356 1.672
(BESTM) $K_{1j}$					-.00085 -.068		-.00475 -.374	-.00806 -.637		-.00568 -.446	-.01178 -.933	-.00171 -.136
(AVT) $K_{1j}$						-.00044 -.232			-.00044 -.234			
(REL) $K_{1j}$	-.00030 -9.652	-.00030 -9.558	-.00030 -9.652	-.00030 -9.683	-.00016 -.644	-.00014 -.476	-.00012 -.714	-.00024 -.952	-.00022 -.727	-.00016 -.635	-.00020 -.512	-.00016 -.631
(BESTM) $K_{1j}$					.00011 .51		-.00000 .000	-.00001 .007		-.00016 .010	-.00000 .002	.00026 .171
(AEORM) $K_{1j}$			-.01255 -.727									
(ALNDR) $K_{1j}$												.24531 913
(AUTO) $K_{1j}$				-.01536 -1.627			-.13840 -2.657					
(ALAUO) $K_{1j}$										.17845 2.498		
(AINCOM) $K_{1j}$		.00217 .945	.00235 1.028					-.01674 -.921	-.01572 -.866			
(ALINON) $K_{1j}$										-.01846 -.913	-.00006 -.153	
(DLIC) $K_{1j}$		.01671 1.146						-.04575 -.802	-.45199 -2.853			
(ALPLIC) $K_{1j}$										-.75412 5.419		
(POP) $K_{1j}$					.00004 6.558	.00004 6.656	.00004 1.122	.00004 .842	.00003 .849	.00004 1.059	.00003 .776	.00004 1.026
(POP) $K_{1j}$					.00003 3.667	.00003 3.638	.00004 1.255	.00003 1.140	.00003 1.151	.00004 1.326	.00003 1.095	.00004 1.021
(M2108) $K_{1j}$								-.00001 -.119	.00000 .003	.00001 .121	-.00001 -.136	-.00002 -.143
(M2107) $K_{1j}$								-.00003 -.446	-.00002 -.304	-.00003 -.315	-.00004 -.445	-.00002 -.267
R	.37920	.38040	.38003	.38078	.28009	.19727	.00510	.21764	.21556	.20694	.23040	.20411
r	132.53	80.230	80.046	100.56	17.415	12.355	9.439	9.725	9.660	9.550	11.044	5.404

Total Degrees of Freedom = 3376

Table 3.4  
Offpeak-hour Logarithmic Regressions

VARIABLE	Functional Form											
	1	2	3	4	5	6	7	8	9	10	11	12
Y	PTRIPS	PTRIPS	PTRIPS	PTRIPS	ATRIPS	ATRIPS	ATRIPS	ATRIPS	ATRIPS	ATRIPS	ATRIPS	ATRIPS
CONSTANT	-.14763	-.14702	-.15120	-.15269	.22498	.22505	.23103	.21265	.21272	.23067	.20570	.29238
(AVET) <sub>K1J</sub>						-.12645 -6.859			-.12068 -6.549			
(RELT) <sub>K1J</sub>	-.25944 -8.709	-.23865 -8.662	-.23848 -8.704	-.23941 -9.023	.07105 1.639	.19747 5.720	.07671 2.139	.06773 1.896	.18138 5.449	.06953 1.945	.06774 1.901	.06305 1.785
(PESTM) <sub>1J</sub>					-.12640 -5.856		-.12490 -6.778	-.12063 -6.546		-.12560 -6.620	-.12174 -6.595	-.12527 -6.897
(AVET) <sub>K1J</sub>						.01079 1.297			.00868 1.044			
(EPLW2) <sub>K1J</sub>	-.03177 -2.793	-.03208 -2.815	-.03193 -2.802	-.03108 -2.742	.07423 6.416	.06420 4.830	.07515 6.434	.07232 6.195	.06364 4.800	.07525 6.435	.07320 6.274	.07101 6.138
(BESTWT) <sub>1J</sub>					.01077 1.294		.01183 1.420	.00866 1.041		.01124 1.347	.00869 1.045	.01117 1.356
(AVET) <sub>K1J</sub>						.00455 .753			.00407 .663			
(RELT) <sub>K1J</sub>	-.08466 -10.807	-.08419 -10.599	-.08461 -10.752	-.08525 -11.320	-.08861 -1.052	-.01306 -1.414	-.00499 -.697	-.00825 -1.004	-.01233 -1.337	-.00815 -1.007	-.00998 -1.235	-.01250 -1.560
(PESTOT) <sub>1J</sub>					.00455 .755		.00791 1.278	.00408 .664		.00586 .943	.00035 .137	.00232 .388
(AKODRI) <sub>K1J</sub>			-.00353 -.292									
(ALNODR) <sub>1J</sub>												.06302 7.142
(AUTO) <sub>K1J</sub>				-.08925 -11.319			.02612 2.247					
(ALAUTO) <sub>1J</sub>										.00990 .736		
(ALNCCM) <sub>K1J</sub>		.00304 .405	.00307 .407					.03114 4.053	.03114 4.082			
(ALLNCCM) <sub>1J</sub>											.02563 2.907	.02679 3.067
(DLIC) <sub>K1J</sub>		.00502 .458						-.01108 -.960	-.01108 -.960			
(ALDLIC) <sub>1J</sub>											-.04239 -2.895	
(RCF) <sub>1</sub>					.00390 1.734	.00390 1.460	-.00227 -1.171	-.00236 -1.188	-.00236 -1.156	-.00232 -1.125	-.00246 -1.071	-.00702 -1.896
(RCF) <sub>1</sub>					.00359 2.072	.00359 2.072	.00246 .127	.00173 .090	.00173 .090	.00195 .101	.00113 .059	-.00243 -.127
(EMPLOY) <sub>1</sub>							.01506 1.880	.01432 1.754	.01432 1.754	.01427 1.742	.01294 1.553	.01244 1.540
(EMPLOY) <sub>1</sub>							.00644 .319	.00692 .378	.00692 .338	.00701 .347	.00768 .331	.00979 .490
R	.43847	.43862	.43857	.43856	.24810	.24810	.24810	.24810	.24810	.24810	.24810	.24810
F	188.27	112.96	112.93	147.21	19.415	19.415	14.822	14.715	14.721	14.446	14.613	19.416

Total Degrees of Freedom = 2176

Table 3.5  
Peak-Hour Linear Regressions - Town Volumes

VARIABLE	Functional Forms										
	1	2	3	4	5	6	7	8	9	10	11
Y	PTrips	PTrips	PTrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips	ATrips
CONSTANT	.34690	.20124	.32404	52.490	112.69	48.303	56.217	-29.494	21.512	-53.718	-110.96
(AVET) KIJ					.58369 .669						
(RELT) KIJ	-.00849	-.00680	-.00336	-2.0305	-15.982	-1.9949	-2.0926	-1.127	-1.3935	-2.095	-2.3529
(BESTTM) IJ	-1.493	-1.266	-.562	-.662	-.852	-.634	-.652	-.350	-.407	-.651	-.723
(AVEWT) KIJ				.77001		.78006	.77012	.94682	.59706	2.0329	.23439
(RELWT) KIJ				.292		.286	.273	.316	.192	.662	.075
(BESTWT) IJ					33.651 2.559						
(AVECT) KIJ					-3.5126	.26948	.28280	.91598	.54872	.32961	.21612
(RELCT) KIJ				.27647	-.2439	.346	.362	1.094	.641	.415	.271
(BESTCT) IJ				.360		.174.29	.172.34	198.63	174.89	167.41	146.87
(ANODRI) KIJ				174.08		2.028	2.003	2.294	1.977	1.868	1.588
(ALNODR) IJ				2.076	-.90613 -2.292						
(AUTO) KIJ	-.00027	-.00023	-.00021	-0.07068	.01630	-.07049	-.07116	-.06108	-.06410	-.06674	-.06677
(ALAUTO) IJ	-3.212	-2.884	-2.438	-1.739	.310	-1.677	-1.704	-1.427	-1.429	-1.555	-1.532
(AINCOH) KIJ				-3.7602		-4.2332	-3.7122	-6.1729	-4.5558	-4.6745	-3.043
(ALINCH) IJ				-.623		.677	-.604	-.977	-.706	-.733	-.446
(DLIC) KIJ								-103.66			
(ALDLIC) IJ								-1.125			
(POP) I											
(PCP) J											
(EMPLOY) I											
(EMPLOY) J											
R	.46343	.58/85	.53387	.36301	.45864	.36570	.36337	.44432	.38658	.41020	.39274
F	6.473	7.063	5.591	1.72011	3.019	1.274	1.255	1.271	.907	1.045	.942

Total Degrees of Freedom - 74

**Table 3.6**  
**Peak-Hour Logarithmic Regressions - Town Volumes**

[illegible]

concerning the Abstract Mode Model and consumer preference patterns in urban travel.

Better fit ("R" values) and significance ("f" values at 99% confidence interval) were obtained in all cases from the logarithmic regressions than from the linear regressions, adding support to Quandt and Baumol's linear-in-logs hypothesis. Better fit and significance were also obtained using PTRIPS (percent of trips by a mode) as the dependent variable, rather than ATRIPS (actual number of trips by a mode) indicating that this model is better suited to pure modal split rather than to both modal split and trip generation (refer to Table 1.1 for definition of PTRIPS and ATRIPS). Finally, better fit and significance, in most cases, were obtained from those regressions using input observations aggregated on an origin-town, destination-town, 3-general-modes basis, than from the same data aggregated on an origin-subzone, destination-subzone, 6-specific-modes basis.

The author hypothesizes that to some extent, the low "R" values reflect the fact that consumer preferences in urban travel cannot be completely explained by the measurable attributes of a traveler or of the travel mode he chooses. Factors such as privacy and comfort also play important roles in influencing the trip-making decisions of a traveler. If these subjective elements could be quantified, the trip-decision process would be better explained. Constraints imposed by the availability of data and the amount of data manipulation involved, prevented the author from including these subjective elements in his analysis of the Abstract Mode Model, except for the use of walk times to and from a mode as a measure of convenience. The problem of evaluating factors such as privacy, comfort, and convenience is difficult to solve when secondary data sources are used (sample data collected by study groups other than the individual who is using the data, and not intended for the individual's specific purpose).

The author further contends that the poor correlation (accuracy) which resulted in all regressions performed on the subzone data (Tables 3.1 to 3.4) was due to the manner in which these observations were aggregated and used, rather than from the explanatory variables and formulations chosen. Examination of the means of the dependent variables, PTRIPS or ATRIPS, from these regressions add support to this argument. For the peak-hour and offpeak-hour linear regressions, the values for the mean of ATRIPS were 1.945 and 1.723 respectively, indicating that the average input observation consisted of less than two trips by a mode. In effect,

modal choice was practically non-existent. Further examination of printouts of the person-trip observations aggregated by origin, destination, and mode showed that a good many consisted of only a single trip by a single mode between a given O-D pair (ATRIPS = 1.00). The result was an attempt by the varying explanatory variables in a given functional form to explain little or no variation in the dependent variable (PTRIPS or ATRIPS), or low "R" values (poor statistical fits). Modal split cannot be explained when little or no modal split has been recorded. Variation in travel volume cannot be explained by a sample biased toward uni-modal, single-trip observations.

This hypothesis of poor fit because of poor data aggregation prompted the author to reaggregate the same data one level higher, on the town basis and by the three general urban travel modes. The better results (Tables 3.5 and 3.6) justified this additional data manipulation, and further pointed out the exacting data structure demanded by the use of the Abstract Mode Model.

From Tables 3.1 to 3.6, it can be seen, especially for the ATRIPS functional forms, that adding more independent variables to a given functional form does not significantly improve the correlation in the new functional form created. Also, better correlation was obtained for a functional form containing the "BEST" values of given travel attributes than for the same functional form containing the "ACTUAL" values of the same travel attributes in place of the "BEST", indicating that the Abstract Mode method of using absolute impedances to travel was at least as good as methods employed by other models.

In conclusion, if the null hypothesis of this thesis ( $H_0$ ), was that the Abstract Mode Model can be used to predict demand for urban transportation, the author did not find conclusive evidence to reject that hypothesis. Data structure and the randomness of consumer travel patterns influenced the nature of the results obtained. Good correlation was obtained for logarithmic regressions using input observations aggregated at a town basis, the "R" values varying between 0.83 and 0.88. All these functional forms were significant at a 99% confidence interval or greater ("F" values).

The estimated regression coefficients ( $\beta$ 's) of the independent variables used in the Abstract Mode formulations were as expected in some cases and contrary to those expected in others.

For the travel attributes, the most unexpected result was the large contribution to the explanatory powers of an estimated equation the cost variables provided, while the travel time variables contributed little or no explanatory power to a given estimated equation. Table 3.7 affords a comparison of the simple correlation coefficients of the travel attributes ("r" values) for the peak-hour logarithmic regressions calculated at an origin-destination-town basis.

Table 3.7  
"r" Values - Logarithmic Peak-hour Regressions,  
Town Basis

<u>Travel Time</u>		<u>Walk Time</u>		<u>Out-of-Pocket Cost</u>	
AVET	0.02	AVEWT	0.55	AVECT	-0.53
BESTTM	0.04	BESTWT	0.21	BESTCT	0.15
RELT	-0.01	RELWT	0.53	RELCT	-0.62

This result is contrary to the generally accepted notion that travel time is more powerful than travel cost in explaining trip-making patterns and modal choice.<sup>12,21,22,27,28</sup> That cost was more important than time in all regressions performed in this study makes the author cautious in interpreting its implications. If one has knowledge of the study area the author's data encompasses, and, keeps in mind some of the peculiarities present in the data (Chapter 2), a plausible explanation of this unexpected result emerges. Boston, like many older cities in this country, has a well established transit system, especially within the study area chosen, both onstreet (bus, trolley) and offstreet (rapid rail, railroad commuter, trolley). A densely populated area with high daily travel volumes by all modes exists. The results, especially during the peak hours, are low, near-equal values of travel speed (high values of travel time) for auto, taxi, and transit for on-street travel.<sup>6,28</sup> For offstreet travel, since station spacings are more closely spaced for rail transit serving dense urban areas than for less-dense areas, transit travel times are increased (speed decreased), decreasing the exclusive-right-of-way advantages of rail transit. Offstreet vehicle travel times closely approximate on-street vehicle travel times in this high-density area, resulting in little or no variation in travel times between competing modes (low "r" values when correlated against travel volume).<sup>6,28</sup>

As mentioned in Chapter Two, the fact that many person-trip observations contained zero values of out-of-pocket cost for the auto modes, moderate values of out-of-pocket cost for the transit modes, and high values of out-of-pocket cost for the taxi mode, would result in significant variations in out-of-pocket cost between the competing modes. When correlated against travel volume, where auto trips dominate over transit trips, and transit trips dominate over taxi trips, the result would be high "r" values for the cost variables.

Another unexpected result was the fact that the signs of the walktime variables consistently were contrary to that expected (positive), since one would expect travel volume by a mode to increase as the walktimes to and from that mode decreased (negative sign). The only explanation offered to account for this result is the fact that, transit trips are more prominent than auto trips or taxi trips for trip-ends more closely spaced in a high-density area, because transit is more readily available and is more convenient. As the distance between trip ends increases, direct transit service between these trip-ends is usually less established and less frequent, making the auto mode more desirable. The travel volume between more widely spaced trip ends is usually less than the travel volume between more closely spaced trip ends. Since the former type of trip is usually undertaken more by the auto mode than by the transit mode, the auto mode implying lower values of walktime than the transit modes, the result could be a positive correlation between walktime and travel volume, travel volume decreasing as walktime decreases, and vice versa.

In summary, travelers do not regard walktime and out-of-pocket cost as costs when traveling by the auto mode. Because of this, high negative correlation was found to exist between out-of-pocket cost and travel volume, while high positive correlation was found to exist between walktime and travel volume. Because of the relative insensitivity in value of travel time between alternative modes, low correlation was found to exist between travel time and travel volume. In general, the "relative" travel attributes possessed better fits ("r" values) and significance ("t" values at 99% confidence interval) than the "best" travel attributes. The regression coefficients ( $\beta$ 's) were fairly consistent from one functional form to another within the same regression, indicating no problems of multicollinearity existed. Contrary signs existed the most for the walktime variables.

For the subzone regressions, it was desirable to ascertain whether the regression coefficients ( $\beta$ 's) of each variable from two different sample populations (peak and offpeak) were the same for all practical purposes, indicating that consumer preference patterns do not change at different times of the day.

The null hypothesis,  $H_0: \beta_1 = \beta_2$ , was tested against the alternative hypothesis,  $H_1: \beta_1 \neq \beta_2$ , at a 95% confidence interval ( $\pm t_{95} = \pm 1.96$ ).

The result was that the difference between values for the same regression coefficients estimated for the peak-hour and offpeak-hour samples was negligible for many of the ATRIPS functional forms (reject  $H_1: \beta_1 \neq \beta_2$ ), indicating that consumer preference patterns do not differ significantly over time. Four of the six possible cases for the PTRIPS functional forms had significant differences in the mean values of their regression coefficients (reject  $H_0: \beta_1 = \beta_2$ ), indicating that consumer preference patterns do differ over time. Since the PTRIPS functional forms possessed better fits and significance than the ATRIPS functional forms, along with more correct signs for the variables regression coefficients, the author contends that the evidence was sufficient enough to conclude that consumer preference patterns do vary over time (reject  $H_0$  and  $\beta_1 \neq \beta_2$ .)

For the environmental descriptors of the traveler and trip ends, the population and employment variables were found to contribute little or nothing to the explanatory power of an estimated equation for all the regressions performed (low "r" values). In many cases, their estimated regression coefficients ( $\beta$ 's) possessed contrary signs (negative instead of positive) and were not statistically significant at a 90% confidence interval or greater.

For the environmental descriptors of the traveler, the driver's license and auto ownership variables computed on the per-mode basis (DLK and AUTO) contributed the most explanatory powers to an Abstract Mode formulation for all regressions performed (high "r" values), consistently were significant at a 90% confidence interval or greater, and had signs as expected (positive) in most cases. In general, those variables computed on a per-all-modes basis (ALNODR, ALAUTO, ALDLIC, ALINCM) possessed lower "r" values, more contrary signs, and lower "t" values (significance) than did their counterparts calculated on a per-mode basis (ANODRI, AUTO, DLIC, AINCOM).

### 3.3 STRENGTHS AND WEAKNESSES OF THE MODEL

The strengths and weaknesses of the Abstract Mode Model uncovered in this research investigation center, in one way or another, around the model's data requirements.

This model, as stated by Quandt and Baumol, does minimize the effect of incompleteness of data<sup>4</sup>. Observations for all modes between a given origin zone-destination zone pair were not prerequisites for the use of this model, nor were observations for all origin zone-destination zone pairs. By characterizing a mode in terms of values of the several variables that affect the desirability of the mode's service to the public, such as travel time, walk time, and out-of-pocket cost modal neutrality and trip-end neutrality is observed. The model assumes that a person chooses among modes purely on the basis of their observed characteristics. Trip-ends are characterized by impedance factors ("best" values of each travel attribute between an O-D pair) for travel time, walk time, and cost and by environmental descriptors such as population and employment levels.

Another strength of this model, because of its modal neutrality, is that the end result desired from the estimation of an Abstract Mode formulation, a travel demand predictive capability for the area under consideration, can be applied to any mode, present or future (hence the name "abstract mode"). As pointed out in Chapter One, this predictive capability will become most important in the future as planners and designers look to new travel modes to solve the ever-increasing urban transportation problem.

Finally, a strength of the Abstract Mode Model, perhaps not too evident at this time, is its use in evaluating consumer preferences in urban travel. It was hypothesized earlier that the measurable attributes of a mode can be used to analyze consumer travel patterns. Since the Abstract Mode Model preserves modal neutrality, in the sense that all present or future modes are "abstract", the estimated regression coefficients in a given formulation represent a cross-section of the observed travel behaviors of a heterogeneous population using a variety of alternative travel modes. Section 3.4 illustrates the model's use, along with the tradeoff ratio concepts, in evaluating consumer's preferences and motivations in travel.

A major weakness of this model, for urban areas at least, is the massive data requirements, and subsequent data manipulation capabilities, demanded by this model. When secondary data sources are used, such as the 1963 BRPP home-interview surveys, the data is often far from the form required by the model, and is often inadequate in scope. To cite the author's 14,000 peak-hour, person-trip observations for the study area under consideration were extracted in unordered form from three magnetic computer tapes containing 133,000 total person-trip observations. These observations had next to be sorted by origin, destination, and mode, and by destination, origin, and mode. Once sorted, the person trip observations for each origin subzone, destination subzone, and specific travel mode were aggregated, mean values of each variable calculated, the "best" values of each travel attribute for each O-D pair computed, the "relative" values computed, and finally the resulting values output as a single observation to the Abstract Mode Model.

Though these steps may seem relatively straightforward, especially since they were performed on a computer, the computational time and effort involved far exceeded that of the other task done in this study. The end result was that 14,000 observations were insufficient to describe trip-making at the subzone basis (Tables 3.1 and 3.2) and further manipulation was involved to reaggregate the data at a higher level, on a town basis, and by the three general travel modes. Better regressions were obtained but also increased generalization due to the higher-level aggregation.

Finally, perhaps not a weakness in the true sense, is the fact that an Abstract Mode equation is estimated by regression techniques, requiring that the input data be amenable to regression. Regression techniques fail if there is little or no variation in the dependent variable (in this case, travel volume for the subzone regressions), or there is little or no variation in value of the independent variables with variation in value of the dependent variable (travel time, for example). Since less variation in value often occurs in intra-city travel for travel attributes than for inter-city travel, and due to other peculiarities often found in the survey data (zero values for walk time and cost for the auto modes), the real world situation cannot always be accurately predicted by regression. To obtain variation in the dependent variable, travel volume, it is often necessary to either aggregate the trip observations at a different level (town basis in this study) or to secure an unduly

large data base ( >> 14,000 person-trip observations in this study). It would seem advisable to consider other models in preference to the Abstract Mode Model when these conditions exist. The Abstract Mode Model was designed for inter-city travel, where the data problems described above are minimal. It can be used for intra-city travel, and is effective, if one is willing to undergo the time and effort that may be involved in data acquisition, aggregation, and manipulation.

#### 3.4 MODEL RESULTS PLUS TRADEOFF RATIOS \_ DESIGN IMPLICATIONS

For analysis purposes in transportation systems design, it would be meaningless to compute the tradeoff ratios from regression coefficients of travel attributes which possessed signs contrary to those expected, and which were not significant or reliable in explaining variations in the dependent variable, travel volume by a mode. These two situations, contrary signs and insignificance, were present in many of the estimated equations for the subzone regressions, peak-hour linear and log, and offpeak-hour linear and log. The result was that no meaningful tradeoff ratios could be computed from these regressions, in terms of regression coefficients with both expected signs and statistical significance at a 95% confidence interval or greater. A similar situation existed for the peak-hour, linear, town regressions, and for the walk time variables (contrary sign for  $\beta$ 's) in the peak-hour, logarithmic, town regressions. However, in the latter regressions, the travel time and out-of-pocket cost variables consistently had  $\beta$ 's with signs as expected (negative), and which were significant at a 95% confidence interval or greater.

To illustrate the calculation of the tradeoff ratios from a given Abstract Mode formulation and their meaning in the context of transportation systems design, they were computed for travel time and out-of-pocket cost from the peak-hour, logarithmic, town regressions. Their development also leads to one final consideration always of interest to the planner - the value of time spent in travel.

In retrospect, the Tradeoff Ratio is defined as the ratio of compensating change in value of one travel attribute relative to another at a constant level of travel volume or for travel time and out-of-pocket cost:

$$T_{TC} = \frac{\frac{\text{Linear}}{d\bar{Y}} \frac{d\bar{X}_{AT}}{d\bar{X}_{AC}}}{\frac{\text{Linear-in-Logs}}{d(\log \bar{Y})} \frac{d\bar{X}_{AT}}{d\bar{X}_{AC}}} = \frac{d\bar{X}_{AT}}{d\bar{X}_{AC}} \frac{d(\log \bar{Y})}{d\bar{Y}}$$

Where  $\bar{Y}$  = travel volume

$\bar{X}_{AT}$  = actual value of travel time

$\bar{X}_{AC}$  = actual value of out-of-pocket cost

Using the expressions for the tradeoff ratios derived in Section 2.2, the tradeoff ratios between travel time and out-of-pocket cost were computed from the peak-hour logarithmic, town regressions for each of the seven trip generation-modal split abstract mode formulations (Table 3.8).

Table 3.8

Computed Tradeoff Ratios for Travel Time and  
Out-of-Pocket Cost-Logarithmic Town Regressions

	$X_{AT} = X_{BT}$	$X_{AT} = X_{BT}$	$X_{AT} \neq X_{BT}$	$X_{AT} \neq X_{BT}$
	$X_{AC} = X_{BC}$	$X_{AC} \neq X_{BC}$	$X_{AC} = X_{BC}$	$X_{AC} \neq X_{BC}$
<u>Selection</u>	<u><math>T_{TC}</math></u>	<u><math>T_{TC}</math></u>	<u><math>T_{tC}</math></u>	<u><math>T_{tc}</math></u>
4	5.65	3.54	0.37	0.26
6	6.20	3.52	0.45	0.26
7	4.76	3.68	0.32	0.25
8	5.54	4.57	0.35	0.29
9	9.37	5.25	0.46	0.26
10	4.70	3.50	0.33	0.25
11	4.27	3.43	0.28	0.22
Mean	5.80	3.93	0.37	0.26

Since a planner would like to design a travel mode which offers the least travel time and out-of-pocket cost to the consumer, and should thus generate maximum system use, the pertinent tradeoff ratios to be examined here are contained in Column One of Table 3.8, where  $T_{TC} = 5.80$ .

If one is willing to recognize that a negative-exponential (linear-in-logs) relationship exists between travel time and out-of-pocket cost and travel volume, the computed tradeoff ratio of travel time with respect to out-of-pocket cost can be directly used to determine the value of a consumer's time spent in travel. In terms of its proper units,

$$T_{TC} = \frac{\frac{d\bar{Y}}{d\bar{X}_{AT}}}{\frac{d\bar{Y}}{d\bar{X}_{AC}}} = \frac{\frac{\text{trips}}{\text{minute}}}{\frac{\text{trips}}{\text{cent}}} = \frac{\text{cents}}{\text{minute}}$$

$$\text{Therefore } T_{TC} = 5.8 \frac{\text{cents}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} = \$3.48/\text{hour}$$

Viewing this hourly rate of \$3.48/hour as even just a rough order of magnitude, one can realize that it far exceeds AASHO's standard estimate of \$1.55/hour for the value of consumer time spent in travel. This value is for those individuals using the "best" mode with respect to both travel time and cost. For those individuals using the mode with the lowest travel time but not the lowest cost, the rate is still higher than AASHO's or is \$2.36/hour (Column 2, Table 3.8). Quite understandably, individuals who use a mode which does not possess the lowest travel time, place a different (and lower) value on their time spent in travel (Columns 3 and 4, Table 3.8).

The preceding observations lead to the conclusion that one hard and fast value cannot be placed on a traveler's time. If an individual has the financial and locational means to choose between competing modes, he will usually choose the mode which offers him the best service. In terms of travel time and out-of-pocket cost, he will usually choose a mode which minimizes a weighted function of both, of these travel attributes. If

this be true, Column one of Table 3.8 is the ideal tradeoff he would like to make between time and cost, which means he values his time spent in travel more highly than previous "one-shot" estimates such as AASHO's or the minimum wage tend to indicate.

#### SUMMARY AND CONCLUSIONS

The effectiveness of the Abstract Mode Model as a prediction device in urban areas and as a tool with which to analyze consumer preferences and motivations in urban travel was tested by applying it to the Boston Metropolitan Area. An extensive series of regressions were performed to test the model's effectiveness, requiring a large amount of data collection, manipulation, and aggregation. If the hypothesis of this study was that the Abstract Mode Model could be used to predict trip generation and modal split in urban areas, this hypothesis could not be rejected.

Poor statistical fits that did occur appeared to result more from sample biases present in the data base used, rather than from the analytical concepts of the Abstract Mode Model. Moreover, the fitted equations tended to indicate that either the particular travel parameters chosen do not by themselves completely explain variations in consumer travel behavior, or that consumer preferences in urban travel are random, and cannot be described by the measurable attributes of a mode.

The Abstract Mode formulations were found to possess better fit and significance in exponential form (linear-in-logs) than in linear form, and the model was found to be better suited to pure modal split than to both trip generation and modal split.

Finally, with the aid of the tradeoff ratio concepts developed in this study, the Abstract Mode Model was found to be effective in analyzing consumer preferences and motivations in urban travel. More specifically, tradeoffs that existed between travel time by a mode and the out-of-pocket cost to travel on that mode were established. From these tradeoffs, the value the consumer places on his time spent in travel was calculated, and found to be higher than previous estimates of this value tended to indicate, such as the minimum wage. It was also found that one hard and fast value could not be placed on a consumer's time.

Approaching trip-making and modal distribution from the consumer's viewpoint is a method seldom utilized because it involves analysis of human behavior both rational and irrational. One cannot begin to enumerate the many intangible factors which influence an individual's trip-making decisions - privacy, comfort, convenience, noise, social status, aesthetics, etc. Many of these factors cannot be taken into account in a transportation demand model, while others can be approximated in terms of the measurable attributes of a mode.

In conclusion, the author recommends that any future research conducted on the Abstract Mode Model should consider the following issues. When the analyst cannot collect his own data in the form he requires it, careful use should be made of secondary sources, such as the 1963 BRPP Home-Interview Surveys. Origin and destination zones must be selected where the analyst knows that there is a choice between alternative modes, and that trip observations by these modes have been recorded. The level of aggregation used should be in keeping with the accuracy of the predictive estimators desired, and at a minimum, would be desirable on a town basis for urban travel.

Secondly, sample breakdown should be in keeping with the classes of travelers to be analyzed. In this research study, subdivision of daily travel into the peak hours and offpeak hours appears justified, because the regressions tended to indicate that consumer preference patterns varied over time. The computation of the tradeoff ratios (Section 3.4) pointed out the fact that the traveler values his time spent in travel highly. The author contends that the value he places on his time will vary with his income level, which would suggest a sample breakdown by at least general income groupings (low, medium, high). Breakdown by trip purpose, work and non-work, also appears desirable.

Why does a person take a trip? Why does he choose mode "X" rather than mode "Y"? Why does he value one travel characteristic more highly than another? A few questions such as these have been answered in varying degrees by this research study. Many have been left unanswered. Only future research by the author and others will provide answers to these questions.

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